CHAPTER 5

GENERAL POWER PLANT FACILITIES DESIGN

Section I. INSTRUMENTS AND CONTROL SYSTEMS

5-1. General

Input adjustments will be designed to be delegated to automatic control systems except during startup, shutdown, and abnormal operating conditions when the operator. displaces or overrides automatic control functions.

5-2. Control panels

a. Types and selection.

(1) *General types.* Control panels used in power plants may be free standing or mounted on a wall or column, as appropriate.

(2) *Central control panel selection.* Control panels for use in central control rooms will be enclosed and of the dual switchboard, duplex switchboard, dual benchboard, control benchboard, or control desk type depending upon the size of the plant and complexity of the instruments and controls to be mounted. When control panels have complex wiring (piping and devices mounted in the interior) the vertical panel section will be provided with rear or walk-in access for ease in erection and maintenance. Frequently the floor of the walk-in space is dropped .2 or 3 feet below the raised control room floor to simplify cable and tubing entrance to the panel interior and to increase space for terminals. A dropped floor will be provided for proper access to any benchboard section of a panel. The shape of the panel will be selected using the following criteria:

(a) Space availability in the control room.

(b) Number of controls and instruments to be mounted.

(c) Visibility of the controls and instruments by the plant operators.

(d) Grouping and interrelationship of the controls and instruments for ease of operation and avoidance of operating error.

b. Location of panels.

(1) *Control room.* The various panels located in the central control room will be arranged to minimize operator wasted motion. In a unitized power plant (one without a header system), provide a boiler-turbine mechanical panel (or section) for each unit with separate common panel(s) to accommodate compressed air, circulating water, service water and like system which may pertain to more than one unit. Coal handling, ash handling and water treating panels will not be located in the central control room unless the plant is small and the operating crew may be reduced by such additional centralizing. If the plant has a header system which is not conducive to boiler-turbine panels, group controls and instruments into a boiler panel for all boilers and a turbine generator panel for all turbines whenever practicable. Usually, a separate electrical panel with mimic bus for the generators and switchgear and switchyard, if applicable, will be provided regardless of whether the mechanical instruments are grouped on a unit basis or a header basis.

(2) *Local panels.* These will be mounted as close to the equipment (or process) they are controlling as is practical.

c. Instrument selection and arrangement on panels. Selection and arrangement of the various controls, instruments and devices on the panels will be generally in accordance with the guidelines of Tables 5-1,5 -2,5-3 and 5-4, and the following

(1) *Items.* Mechanical items will be grouped by basic function (i.e., turbine, boiler, condensate, feedwater, circulating water, service water and like systems), Burner management controls will be obtained as an "insert" or subpanel which can be incorporated into the boiler grouping of controls and instruments. Such an insert may include remote lightoff and startup of burners if desired. Electrical items will be grouped by generator, voltage regulator, switchgear and like equipment items in a manner which is easily incorporated into a mimic bus.

(2) *Readability.* Instruments which require operator observation will be located not higher than 6 1/2 feet nor lower than 3 feet above the floor for easy readability.

(3) *Controls, switches and devices.* Those controls, switches and other devices which require manipulation by the operators will be easily accessible and will be located on a bench or desk wherever practicable.

(4) *Indicators versus recorders.* Indicators will be provided where an instantaneous reading of cycle thermodynamic or physical parameters suffices as a check of proper system operation. When a permanent record of plant parameters is desired for eco-

Table 5-1. List of Typical Instruments and Devices to be Provided for Boiler Turbine Mechanical Panel

Measurement or Device	Primary Element: Fluid	Primary Element: Location	Instrument or Device on Panel
Pressure	Steam	Boiler drum	Indicator
	Steam	Boiler atomizing steam	Indicator
	Steam	Turbine Throttle	Indicator
	Steam	Deaerator steam space	Indicator
	Feedwater	BFP discharge	Indicator
	Condensate	Cond. pump discharge	Indicator
	Fuel gas	Boiler burners	Indicator
	Fuel gas	Igniter	Indicator
	Fuel gas	Boiler burne s	Indicator
	Flue gas	Draft points(1	Indicator
	Lube Oil	Turbine generator	Indicator
	Vacuum	Condenser	Indicator
Temperature	Steam	Turbine throttle	Indicator
	Steam	Boiler superheater outlet	Recorder
	Steam	Turbine extraction steam	Recorder
	Air-flue gas	Boiler draft system	Recorder(2)
	Lube Oil	Turbine generator	Recorder
Flow	Steam	Boiler main steam	Recorder & totalizer
	Air	Boiler FD f n discharge	Recorder
	CO_2	Boiler flue(3)	Recorder
	Feedwater	Boiler main supply	Recorder
	Feedwater	Boiler Attemperator	Recorder
	Fuel gas	Boiler burner supply	Recorder & totalizer
	Fuel oil	Boiler burner supply	Recorder & totalizer

Notes:

(1) Including FD fan discharge, air inlet & outlet to air preheater, windbox, furnace draft, inlet & outlet to economizer, gas inlet and outlet to air preheater, overfire or primary air pressure, and ID fan discharge.

(2) Multi-point electronic type to track air and gas temperatures through the unit.

(3) May be used for combustion controls instead of steam flow-air flow.

(4) Usually in condensate system, boiler feed system and process returns.

Table 5-1. List of Typical Instruments and Devices to be Provided for Boiler Turbine Mechanical Panel. (Continued)

Measurement or Device	Primary Element: Fluid	Primary Element: Location	Instrument or Device on Panel
Level	Feedwater	Boiler drum	Recorder
	Condensate	Deaerator, Condenser Hotwell	Recorder
	Coal	Bunker	Indicator or pilot lights
Conductivity	Condensate	Cells as required[4]	Recorder
Manual-automatic stations	--	Combustion control system, condensate and feedwater control systems, steam attemperator, and as required	Each station
Motor control switches	--	Starters for draft fans, BF pumps, condensate pumps, vacuum pumps, fuel pumps, lube oil pumps, turning gear, turbine governor and like items	Each switch
Ammeters	--	Major motors (high voltage): draft fans, BF pumps	Indicator
Alarms	--	Points as selected for safe operation	Annunciator section for boiler turbine panel
Burner Management	--	Boiler burner system	Insert on boiler-turbine panel
Indicating	-	As required to start up and monitor boiler and turbine.	Each light

Notes: See first page of Table.

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Table 5-2. List of Typical Instruments and Devices to be Provided for Common Services Mechanical Panel

Measurement or Device	Primary Element: Fluid	Primary Element: Location	Instrument or Device on Panel
Pressure	Steam	Main steam header(1)	Recorder
	Steam	Extraction steam header(1)	Indicator
	Fuel gas	Supply to plant	Indicator
	Fuel oil	supply	Indicator
	Fuel oil	Burner pump discharge	Indicator
	Circ. water	Discharge header	Indicator
	Water	Service water	Indicator
	Water	Closed cooling water	Indicator
	Water	Fire system	Indicator
	Air	Instrument air	Indicator
	Air	Service air	Indicator
	Air	Atmosphere	Barometer
Temperature	Steam	Extraction steam header(1)	Indicator
	Fuel Oil	supply	Indicator
	Various	As required	Recorder(2)
Viscosity	Fuel oil	Pump and heater sets	
Flow	Steam	Turbine throttle(1)	Recorder
	Steam	Extraction to process	Recorder & totalizer
	Fuel gas	Supply to plant	Recorder & totalizer
Level	Fuel oil	Tank(s)	Indicator
	Condensate	Tank(s)	Indicator
Manual-automatic stations	--	Pressure reducing station, misc. air operated devices	Each station
Motor control switches	--	CW pumps, cooling tower fans, air compressors, condensate transfer pumps, service water pumps, fuel transfer pumps, and like items	Each switch

Notes: (1) For header systems only
(2) Multi-point electronic type

Table 6-2, List of Typical Instruments and Devices to be provided for Common Services Mechanical Panel. (Continued)

Measurement or Device	Primary Element: Fluid	Primary Element: Location	Instrument or Device on Panel
Ammeter	-	Major (high voltage) motors; CW pumps, cooling tower fans	Indicator
Alarms	- -	Points as selected for safe operation	Annunciator section for common panel
Indicating	- -	As required to start-up and monitor principal common systems	Each light

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nomic or engineering accountability purposes, recorders will be provided.

d. Ventilation. All panels which house heat producing instruments will be ventilated or air conditioned to prevent overheating of the instruments. For panel~in the central control room, this will be accomplished by having a filtered air intake and mechanical exhaust arrangement to circulate cool air from the air conditioned control room through each enclosed panel wherever practicable. Local panels, as a rule, have only gages and other devices which emit little heat and do not require special ventilation.

e. Illumination. In a central control room, the best illumination is a “light ceiling” with diffuser type suspended panels to give a shadowless, even level of lighting throughout the control room. Levels of illumination at bench tops of 75-foot candles, plus or minus 10-foot candles, will be provided. However, caution must be used when designing lighting for control rooms utilizing electronic digital controls with cathode ray tube (CRT) display as excessive illumination tends to wash out displays. In areas with electronic digital controls with CRT displays, the level of general illumination will be maintained at 15- to 25-foot candles. Local panel illumination will be accomplished by means of a canopy built into the top of the panel. Local switch control will be provided at each canopy light.

5-3. Automatic control systems

a. Types. Control systems and instruments may be pneumatic, ac or dc electronic, electronic digital, combination pneumatic and electronic, or hydraulic. Mechanical-hydraulic and electro-hydraulic systems will be utilized in connection with turbine generator speed governing control systems. Pneumatic controls will be used for power plant units of 30 MW or less. Applications include: combustion control, feedwater regulation, desuperheating and pressure reducing station control, heater drain control, and boiler feed recirculation control. Pneumatic systems are economical, reliable, and provide smooth, modulating type of operation. For plants where the arrangement is dispersed and precision is required, electronic controls and instruments will be provided in lieu of the pneumatic type because of the sluggishness of pneumatic response where long distances are involved. Electronic digital controls have recently become economically competitive with analog pneumatic and electronic controls and offer the advantage of' ‘soft-wired” control logic and programmable versatility. With electronic controls it is required to use pneumatically operated valves with transducers to convert the electronic signals to pneumatic at the pneumatic valve operator.

b. Combustion controls. Combustion controls for steam generators will be based on the conventional indirect method of maintaining steam pressure. Systems will be of the fully metering type, designed to hold steam pressure within plus or minus 1 percent of the controller setting with load changes of 5 percent per minute; under the same rate of load change, excess air will be maintained at plus or minus 2 percent of the control setting. *(Note:* With stoker fired boilers having limited heat inputs from suspension heat release, the tolerances on steam pressure will be greater than 1 percent.)

Table 5-3. List of Typical Instruments and Devices to be Provided for Electrical (Generator and Switchgear) Panel

Measurement or Device	Instrument or Device on Panel	Notes
	For Each Generator	
Generator gross output	Wattmeter	--
Power Factor	P.F. Meter	
Generator ac current	AC ammeter	- -
Generator ac volts	AC voltmeter	- -
Generator dc current	DC ammeter	- -
Generator dc volts	DC voltmeter	- -
Generator ac current (for individual phases)	AC ammeter control switch	For phase measurement selection - -
Generator ac volts (for individual phases)	AC voltmeter control switch	For phase measurement selection - -
Generator synchronizing	Synchronizing control switch	
Generator synchronizing	Separate panel section	Incl. synch. lamps and meters for incoming and running indication
Oil circuit breaker trip	OCB control switch	If step-up transformation included
Generator field breaker	Field breaker control switch	- -
Voltage regulator	Voltage reg. transfer voltmeter	
Voltage regulator	Manual voltage regulator	- -
Voltage regulator	Auto. voltage reg. adjuster	- -
Voltage regulator	Voltage reg. transfer switch	- -
Unit governor	Governor control switch, raise-lower	- -
Unit trip	Trip pushbutton	- -
Unit reset	Reset pushbutton	- -
Unit speed	Speed indicator	- -
Unit temperatures	Electronic recorder	For turbine and generator temperatures
Generator alarms	Annunciator	With test and reset pushbuttons
Miscellaneous	Indicating lights	For switches and as required
Supervisory	Recorders	Vibration, eccentricity

Table 5-3. List of Typical Instruments and Devices to be Provided for Electrical (Generator and Switchgear) Panel. (Continued)

Measurement or Device	Instrument or Device on Panel	Notes
For Switchgear		
2.4 or 4.16 kV unit switchgear	Breaker control switch	If higher plant auxiliary voltage required
2.4 or 4.16 kV common switchgear	Breaker control switch	If required
2.4 or 4.16 kV feeders	Breaker control switches	For plant auxiliaries and/or for outside distribution circuits as required.
480 V unit switchgear	Breaker control switch	
480 V common switchgear	Breaker control switch	
480 V feeders	Breaker control switches	For plant auxiliaries as required
Swithgear ac current	AC ammeters	One for each switchgear with switch
Switchgear ac volts	AC voltmeters	One for each switchgear with switch
Switchgear alarms	Annunciator	With test and reset push-buttons
Miscellaneous	Indicating lights	For switches and as required
Intraplant communication	Telephone handset	

Notes: (1) If a high voltage switchyard is required a separate panel may be required.
(2) For relays see Chapter 4, Section V; generator and auxiliary power relays may be mounted on the back of the generator walk-in bench- board or on a separate panel.

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Table 5-4. List of Typical Instruments and Devices to be Provided for Diesel Mechanical Panel

Measurement or Device	Primary Element: Fluid	Primary Element: Location	Instrument or Device on Panel
Pressure	Fuel gas	Supply to engine	Indicator
	Fuel oil	Supply to engine	Indicator
	Lube oil	Supply to engine	Indicator
	Lube oil	supply to turbocharger	Indicator
	Comb. air	Turbocharger discharge	Indicator
	Comb. air	Filter downstream	Indicator
	Cooling water	Pump discharge	Indicator
	Starting air	Air receiver	Indicator
Temperature	Exhaust	Each cylinder and combined exhaust	Indicator(l)
	Cooling water	Supply to engine	Indicator
	Cooling water	Return from engine	Indicator
Level	Jacket water	Surge tank	Indicator
	Lube Oil	Sump tank	Indicator
	Fuel	Bulk storage tank	Indicator
	Fuel	Day Tank	Indicator
Motor control switches (or pushbuttons)	-	Jacket water pumps, radiator (or cooling tower) fans, fuel oil pumps, centrifuges, and like auxiliaries	Each switch
Alarms	- -	Low lube oil pressure, low jacket water pressure, high lube oil temperature, high jacket water temperature, high and low day tank levels	Annunciator

Notes: (1) With selector switch.

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c. Feedwater regulation. A three element feedwater regulator system will be provided for steam power plant service. Such a system balances feedwater input to steam output subject to correction for drum level deviations caused by operating pressure variations (drum swell).

d. *Attemperator control system.* Each power plant steam generator will have superheat (attemperator) controls to maintain superheat within the limits required for protection of the turbine metal parts against thermal stress and for preventing excessive reduction in part load turbine efficiency. Injection of desuperheating water (which must be high purity water, such as condensate) will be done between stages of the boiler superheater to reduce chances of water carryover to the turbine. An attemperator system having a controller with a fast response, derivative feature will be provided. This type of controller anticipates the magnitude of system deviations from the control set point in accordance with the rate of change of superheat temperature. Automatic positive shutoff valve(s) will be provided in the desuperheating water supply line upstream of the desuperheater control valve to prevent dribbling of water to the desuperheater when the controls are not calling for spray water.

e. Closed heater drain controls. Although it is thermodynamically preferable to pump the drains from each feedwater heater forward into the condensate or feedwater stream exiting from the heater, the expense and general unreliability of the low NPSH pumps required for this type of drain service will normally preclude such a design. Accordingly, the drains from each heater will normally be cascaded to the next lower pressure heater through a level control valve. The valve will be located as closely as possible to the lower pressure heater due to the flashing which occurs because of the pressure reduction at the outlet of the level control valve. Each heater will be provided with two level control valves. The secondary valve only functions on startup, on malfunction of the normal valve, or sometimes during light loads when pressure differential between heaters being cascaded becomes very small. The secondary valve frequently discharges directly to the condenser. Such a complexity of controls for heater drains is necessary to assist in preventing problems and turbine damage caused by turbine water induction. Water induction occurs when feedwater header tubes or level control valves fail, causing water to backup into the turbine through the extraction steam piping. Refer to Chapter 3, Section VII.

f. Boiler feed recirculation controls. An automatic recirculation system will be installed for each pump to bypass a minimum amount of feedwater back to the deaerator at low loads for protection against boiler feed pump overheating. A flow signal from the suction of each pump will be used to sense the preset minimum safe pump flow. This low flow signal will open an automatic recirculation valve located in the piping run from the pump discharge to the deaerator. This recirculation line poses minimum flow through a breakdown orifice for pressure reduction to the deaerator. The breakdown orifice will be located as closely as possible to the deaerator because flashing occurs downstream. When pump suction flow increases to a preselected amount in excess of pump minimum flow, the recirculation valve closes. The operator will be able to open the recirculation valve manually with a selector switch on the control panel. Designs will be such as to preclude accidental closing of the valve manually. Such an operator error could cause flow to drop below the safe level quickly, destroying high pressure pumps.

g. *Other control systems.* Desuperheating, pressure reducing, fuel oil heating, and other miscellaneous power plant control systems will be provided as appropriate. Direct acting valves will not be used. Control valves will be equipped with a matching valve operator for positive opening and closing action. Deaerator and hotwell level control systems are described in Chapter 3, Section VII.

5-4. Monitoring instruments

a. Types.

(1) Control system components will include sensing devices for primary fluids plus transmitters, transducers, relays, controllers, manual-automatic stations, and various special devices. Table 5-5 lists sensing elements for controls and instruments. Instruments generally fall into two classifications—direct reading and remote reading.

(2) Direct reading instruments (e.g., thermometers, pressure gages, and manometers) will be mounted on local panels, or directly on the process piping or equipment if at an accessible location. Locally mounted thermometers will be of the conventional mercury type or of the more easily read (but less accurate) dial type. Type selected will depend on accuracy required. Pressure gages for steam or water service will be of the Bourdon tube type.

(3) Remote reading instruments (recorders, integrators, indicators and electrical meters) will be mounted on panels in the central control room. These instruments will have pneumatic or electronic transmission circuits. Sometimes the same transmitters utilized for control system service can be utilized for the pertinent remote reading instrument, although for vital services, such as drum level, an independent level transmitter will be used for the remote level indicator.

Table 5-5. Sensing Elements for Controls and Instruments.

Element	Type		Common Applications	
			Control	Instrument
Flow	Mechanical	Batch	Filling containers	Weigh Scale
	Totalizing			Totalizing positive displacement water and gas meters
	Variable differential pressure with constant area	Continuous and totalizing	Proportioning large flows	Orifice, flow nozzle, and nozzle meters
	Variable differential presure with variable area	Combustion	Air or glas flow	Control valves
	Constant differential pressure with variable area	Tapered tube and float	Proportioning small flows	Rotameter
	Variable differential	Pitot tube Velocity	Air or gas flow	Dampers
	Variable velocity anemometer	Electric resistance of hot wire affected by velocity of flow	--	Potentiometer

Table 5-5. Sensing Elements for Controls and Instruments. (Continued)

Element	Type		Common Applications	
			Control	Instrument
Motion	Centrifugal	--	Speed governs	Tachometer
	Vibrating reed	--	Speed governs	Tachometer
	Relative motion	--	--	Stroboscope
	Photo-electric cell	--	Limit control	Counter
Chemical	Flue gas analysis	--	Combustion control	Orsat
	Water analysis	--	Water treatment	--
	Fuel analysis		--	--
Physical	Specific gravity	--	--	Hydrometer for liquids
	Weight	--	--	Scales for solids
	Humidity		--	Hygrometer
	Smoke density	--	--	Ringelman chart
	Gas density		Combustion	$C0_2$ meter
	Heat	Combination of water flow and temperature differential	Combustion	Btu meter
Electric and electronic	Photo-conductivity		Flame safe-guard	Photo-electric cell Smoke density
	Electric conductivity	Probes	Alarm	pH of water Oil in condensate

Source: NAVFAC DM3

Table 5-5. Sensing Elements for Controls and Instruments. (Continued)

Element	Type		Common Applications	
			Control	Instrument
Pressure	Mechanical	Bourdon tube Bellows or diaphragm Manometers	Pressure, draft and vacuum regulators	Pressure gage Low pressure, draft and vacuum gages Barometer
	Variable electric resistance due to strain	Pressure transducer	Process pressure regulator	Potentiom. 100 to 50,000 psi
	Variable electric resistance due to vacuum	Thermocouple	Vacuum regulator	High vacuum 1-7000 microns Hg
	Variable electronic resistance due to vacuum	Vacuum tube	Vacuum regulator	High-vacuum down to 0.1 micron Hg
Level	Visual	- -	- -	Gage stick Transparent tube
	Float	Buoyant float	Mechanical level regulator	Tape connected to float
		Displacement	Pneumatic float regulator	Torque
	Differential pressure	Manometer	Level regulator	Remote level gage
	Hydrostatic	Diaphragm in tank bottom	Level regulator	Tank levels with viscous fluids

Table 5-5. Sensing Elements for Controls and Instruments. (Continued)

Element	Type		Common Applications	
			Control	Instrument
Temperature	Solid expansion	Bimetal	On-off thermostats	Dial therm. - 100 to 1000 F
	Fluid expansion	Mercury or alcohol	- -	Glass therm.- 38 to 750 F
		Mercury in coil Organic liquid	Temperature regulators	Dial therm. - 38 to 1000 F 125 to 500 F
		Organic vapor liquid		- 40 to 600 F
		Gas		- 400 to 1000 F
	Thermocouple	Copper-constantan Iron-constantan Chromel-alumel Plat.-plat. rhodium	Temperature regulators	Low voltage - 300 to 600 F O to 1400 F 600 to 2100 F 1300 to 3000 F
	Elec. resistance of metals	Copper Nickel Platinum	Temperature regulators	Potentiom. - 40 to 250 F - 300 to 600 F - 300 to 1800 F
	Optical Pyrometer	Comparative radiant energy	- -	Potentiom. - 800 to 5200 F
	Radiation pyrometer	Radiant energy on thermocouples	Flame safeguard Surface temperature regulation	Potentiom. - 200 to 7000 F
	Fusion	- -	- -	Pyrom.cones -1600 to 3600 F Crayons - 100 to 800 F

(4) Panel mounted receiver gages for pressure, temperature, level and draft will be of the miniature, vertical indicating type which can be arranged in convenient lineups lineups on the panel and are easy to read.

(5) Recorders will be of the miniature type, except for multi-point electronic dot printing recorders which will be full size.

b. Selection. The monitoring instruments for any control system will be selected to provide the necessary information required for the control room operator to be informed at all times on how the controlled system is functioning, on vital process trends, and on other essential information so that corrective action can be taken as required.

5-5. Alarm and annunciator systems

a. *Purpose.* The annunciator system supplements the operator's physical senses and notifies him both audibly and visually when trouble occurs so that proper steps can be taken to correct the problem.

b. General. The alarm system will be both audible and visual. The sounding of the alarm will alert the operators that a problem exists and the visual light in the pertinent annunciator window will identify the problem. Annunciator systems shall provide for the visual display to be distinguishable between new alarms and previous alarms already acknowledged by the operator pushing a button provided for this purpose. New alarms will be signified by a flashing light, whereas acknowledged alarms will be signified by a steady light. Alarm windows will be arranged and grouped on vertical, upper panel sections with corresponding control stations and operating switches within easy reach of the operator at all times. Critical or potentially dangerous alarms will be a different color from standard alarms for rapid operator identification and response.

Section II. HEATING; VENTILATING AND AIR CONDITIONING SYSTEMS

5-6. introduction

This section sets forth general criteria for design of space conditioning systems for a power plant.

5-7. Operations areas

a. Enclosed general operating areas.

(1) *Ventilation supply.* Provide mechanical ventilation for fresh air supply to, as well as exhaust from, the main operating areas, A filtered outside air supply, with heating coils and recirculation option for winter use, will be provided. Supply fans will be selected so that indoor temperature does not rise more than 15°F. above the ambient outdoor air design temperature, and to maintain a slight positive inside pressure with all exhaust fans operating at maximum speed. Ventilation system design will take into account any indoor air intakes for boiler forced draft fans, which can be designed to draw warm air from near the roof of the plant. Supply air will be directed through a duct system to the lowest levels of the plant with particular emphasis on furnishing large air quantities to "hot spots. " The turbine room will receive a substantial quantity of fresh air, supplemented by air from lower levels rising through operating floor gratings. For hot, dry climates, evaporative cooling of ventilation air supply will be provided.

(2) *Ventilation exhaust.* Exhaust fans with at least two speeds are switched so that individual fan and fan speed can be selected according to air quantity desired will be provided. Battery rooms will have separate exhaust systems designed in accordance with TM 5-811-21AFM 88-9/2. It may be economical to remove heat from hot spots with local ducted exhaust systems to prevent heat from being carried into other areas. All exhaust and supply openings will be provided with power operated dampers, bird screens, and means for preventing entrance of rain, sleet and snow.

(3) *Heating.* As much heating as practicable will be supplied via the central ventilation supply system, which will be designed so that maximum design air flow can be reduced to a minimum required for winter operation. Heat supplied by the ventilation system will be supplemented as required by unit heaters and radiation. Heating system design for ventilation and other space heating equipment will be selected to maintain a minimum plant indoor temperature of 55°F. and an office, control room and laboratory area temperature of 68°F.

b. Control room.

(1) The central control room is the operating center of a power plant and will be air conditioned (i.e., temperature control, humidity control and air filtration) for the purpose of human comfort and to protect equipment such as relays, meters and computers. Unattended control rooms may not require comfort conditions but have temperature limits as required by the equipment housed in the room. Control system component manufacturers will be consulted to determine the operating environment required for equipment reliability.

(2) Intermediate season cooling using 100 percent outside air for an economizer cycle or enthalpy control will be life cycle cost analyzed.

5-8. Service areas

a. Toilets, locker rooms and lunch rooms.

(1) Toilets will be exhausted to maintain a negative pressure relative to adjacent areas. All exhaust outlets from a toilet will be a minimum of 15 feet from any supply inlet to prevent short circuiting of air. Toilet exhaust will be combined with a locker room exhaust but not with any other exhaust.

(2) Locker rooms will be exhausted according to the applicable codes and supplied by a heated air supply.

(3) Lunch rooms will be furnished with recirculation heating systems to meet applicable codes; exhaust will be installed. System will be independent of other systems to prevent recirculation of food odors to other spaces.

b. Shops and maintenance rooms. All shops and maintenance rooms will be ventilated according to applicable codes. Welding and painting areas will be exhausted. Heating will be provided by means of unit heaters sized to maintain a maximum of 68 “F. on the coldest winter design day.

c. Offices and laboratories. All offices and laboratories will be air conditioned for human comfort in accordance with TM 5-810-l/AFM 88-8/1. Exhaust will be provided where required for laboratory hoods or other special purposes.

Section III. POWER AND SERViCE PIPING SYSTEMS

5-9. introduction

a. General. Power plant piping systems, designed to transfer a variety of fluids (steam, water, compressed air, fuel oil, lube oil, natural gas) at pressures ranging from full vacuum to thousands of psi, will be engineered for structural integrity and economy of fluid system construction and operation.

b. Design considerations. Piping systems will be designed to conform to the standards listed in Table 5-6. ASME Boiler Pressure Vessel Code Section I governs the design of boiler piping, usually up to the second isolation valve. ANSI B31.1, Code for Pressure Power Piping governs the pressure boundary requirements of most other plant piping (excluding plumbing and drainage piping). Each of these codes provides a detailed description of its scope and limitations.

5-10. Piping design fundamentals

Design of piping system will conform to the following procedure:

a. Select pipe sizes, materials and wall thickness (pipe schedule). Design for the maximum pressure and temperature the piping will experience during either operation or upset conditions. Follow appropriate sections of ASME Section I and ANSI B31.1. Other requirements for welding qualification and pressure vessel design are set forth in ASME Sections VIII and IX. Specify hydrostatic pressure testing requirements in accordance with the codes. Select flow velocities for overall economy.

b. Select piping components and end connections for equipment.

c. Route piping. Make runs as simple and direct as possible. Allow for maintenance space and access to equipment. Do not allow piping to encroach on aisles and walkways. Inspect for interferences with structures, ductwork, equipment and electric services.

d. Include provisions for drainage and venting of all pipe lines.

e. Design pipe supports, restraints and anchors, using accepted procedures for thermal expansion stress analysis. The stress analysis will consider simultaneous application of seismic loads, where applicable. Computer analysis will be used for major three plane piping systems with multiple anchors.

5-11. Specific system design considerations

a. Steam piping. In all steam systems, provisions will be made for draining of condensate before startup, during operation and after shutdown. Steam traps will be connected to low points of the pipelines. Small bore bypass piping will be provided around block valves on large, high pressure lines to permit warming before startup.

b. Circulating water piping. Reinforced plastic piping will be used for salt or brackish water service whenever practicable.

c. *Fuel oil piping.* Fuel oil piping will be designed with relief valves between all block valves to protect against pipe rupture due to thermal expansion of the oil. Fuel oil piping will be designed in accordance with National Fire Protection Association (NFPA) standards and ANSI B31. Piping subject to vibration (such as engine service) will be socket or butt welded, although flared tubing may be used for small lines under 1/2 inch.

d. Insulation. Insulate all lines containing fluids above 120°F. so that insulation surface temperatures remain below 120°F. at 80°F. still air ambient. Provide anti-sweat insulation for all lines which operate below ambient temperatures. Protect all insulation against weather (or wash down water if indoors) and mechanical abuse.

Table 5-7. Characteristics of Thermal Insulations. (Continued)

Form	Material (Composition)	Accepted Max.Temp. For Use °F(1)	Density lb./cu. ft.	K = Typical Conductivity at Mean Temp. °F (Btu/H/ft^2/° per inch) 40	70	100	200	300	500	700	900
Pipe Insulation (con'd)	Plastics (foamed)	175	1-6	0.26	0.28	0.31	--	--	--	--	--
	Rubber (foamed)	150	5	0.23	0.24	0.25	--	--	--	--	--
	Vegetable and animal fiber:										
	Wool felt	180	20	0.29	0.31	0.33	--	--	--	--	--
	Hair felt or hair felt plus jute	180	10	0.27	0.28	0.30	--	--	--	--	--
Insulating cement	85% magnesia	600	18	--	--	0.46	0.52	0.58	--	--	--
	Mineral wool (rock, slag or glass):										
	With colloidal clay binder	1800	24-30	--	--	0.49	--	0.61	0.73	0.83	--

NOTES: (1) These temperatures are generally as maximum. When operating temperature approaches these limits the manufacturer's recommendations should be followed.

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Table 5-6. Piping Codes and Standards for Power Plants. (Continued)

Sponsor	Identification	Title	Coverage
ANSI	B36 series	Iron and steel pipe	Materials and dimensions.
	B16 series and G37.1	Pipe, flanges and fittings	Materials, dimensions, stresses and temperature-pressure ratings.
	B18 series	Bolts and nuts	Bolted connections.
ASTM	--	Testing materials	Physical properties of materials specified in above ASME and ANSI standards.
Major equipment manufacturers (turbines, pumps, heat exhangers, etc.)	--	--	Allowable reactions and movements on nozzles from piping.

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Section IV. THERMAL INSULATION AND FREEZE PROTECTION

5-12. Introduction

Applications. Thermal insulations are used for the following purposes:

a. Limit useful heat losses.

b. Personnel burn protection.

c. Limit heat gains where cold is desired.

d. Prevent icing and condensation.

e. Freeze protection.

5-13. Insulation design

The principal elements of insulation system design and specification areas follows:

a. Selection of surfaces. Define and list the various surfaces, piping, vessels, ductwork, and machinery for which insulation is needed including lengths, areas and temperatures.

b. Insulation systems. For each class or type of surface select an appropriate insulation system: bulk insulation material and miscellaneous materials,coverings, and like items.

c. Economical thickness. Based on the above data, select the economical or necessary thickness of insulation for each class or type of surface.

5-14. Insulation materials

a. *Bulk material.* Refer to Table 5-7 for nomenclature and characteristics of conventional thermal insulations.

b. Restrictions on asbestos. Asbestos insulation, or insulations containing loose, fibrous, or free asbestos are not to be used.

c. *Maximum temperatures.* Each type of insulation is suitable for use at a specified maximum temperature. Design will be such that those maximums will not be approached closely in ordinary applications. All high temperature insulations are more expensive and more fragile than lower temperature products and, in general, the least expensive material which is suitable for the temperature exposure will be selected. Where substantial total insulation thicknesses of 6 inches or more are required, economics may be realized by using two layers of different materials using high temperature material close to the hot surface with cheaper low temperature material on the cold side.

d. Prefabricated insulation. A major part of total insulation cost is field labor for cutting, fitting and

Table 5-7. Characteristics of Thermal Insulations.

Form	Material (Composition)	Accepted Max.Temp. For Use °F(1)	Density lb./cu. ft.	K = Typical Conductivity at Mean Temp. °F (Btu/H/ft²/°F per inch)							
				40	70	100	200	300	500	700	900
Blanket	Mineral wool (rock, slag, or glass):										
	Metal reinforced	1200	6-15	--	--	0.29	0.35	0.42	0.56	--	--
	Felt-flexible type	450	0.5-3	0.23	0.25	0.26	0.34	0.45	--	--	--
	Felt-semi-rigid type	450	2-8	0.24	0.25	0.27	0.35	0.44	--	--	--
	Vegetable and animal fiber:										
	Hair felt or hair felt plus jute	180	10	0.27	0.28	0.30	--	--	--	--	--
Blocks and boards	Calcium silicate	1200	11	--	--	0.33	0.38	0.43	0.53	0.64	0.75
	Cellular glass	800	9	0.37	0.39	0.41	0.43	0.55	--	--	--
	Corkboard (without added binder)	200	6.5-8	0.26	0.27	--	--	--	--	--	--
	Diatomaceous silica	1500	22	--	--	--	--	--	0.60	0.64	0.68
		1900	25	--	--	--	--	--	--	--	--
	85% magnesia	600	11-14	--	--	0.35	0.38	0.42	0.46	--	--
	Mineral wool (rock, slag or glass):										
	Low temp. (asphalt or resin bonded)	200	6-18	0.28	0.29	0.30	--	--	--	--	--
	High temp.-(resin bonded)	600	6-10	--	--	0.28	0.35	0.43	--	--	--
	-(inorganic binder)	1600	16-24	--	--	0.34	0.39	0.44	0.54	0.64	--
	Plastics (foamed)	175	1.6	0.26	0.28	0.30	--	--	--	--	--
	Rubber (foamed)	150	5	0.23	0.24	0.25	--	--	--	--	--

Table 5-7. Characteristics of Thermal Insulations. (Continued)

Form	Material (Composition)	Accepted Max. Temp. For Use °F(1)	Density lb./cu. ft.	K = Typical Conductivity at Mean Temp. °F (Btu/H/ft²/° per inch)							
				40	70	100	200	300	500	700	900
Pipe Insulation	**Asbestos:**										
	Molded amosite and binder	**1200**	**16**	--	--	**0.33**	**0.38**	**0.43**	**0.53**	--	--
	Laminated asbestos paper	**700**	**30**	--	--	**0.40**	**0.45**	**0.50**	**0.60**	--	--
	Corrugated and laminated asbestos paper:										
	4 ply per in.	300	11-13	--	0.54	0.57	0.62	**0.80**	--	--	-
	6 ply per in.	300	15-17	—	0.49	0.51	0.59	**0.69**	--	--	--
	8 ply per in.	300	18-20	--	0.47	0.49	0.57	**0.65**	--	--	--
	Calcium silicate	1200	11	--	--	0.36	0.40	**0.44**	0.55	--	--
	Cellular glass	800	9	0.37	0.39	0.41	0.48	**0.55**	--	--	--
	Cork (without added binder)	200	7-10	0.27	0.28	0.29	0.30	--	--	--	--
	Diatomaceous silica	1500	22	--	--	--	--	--	0.64	0.66	0.71
		1900	25	--	--	--	--	--	0.70	0.75	0.80
	85% magnesia	600	11-14	--	--	0.39	0.42	**0.45**	0.51	--	--
	Mineral wool (rock, slag or glass):										
	Low temp. (asphalt or resin bonded)	200	15	0.28	0.30	0.33	0.39	--	--	--	--
	Low temp. (fine fiber resin bonded)	450	3	0.22	0.23	0.24	0.27	0.31	—	--	--
	High temp. blanket-type (metal reinforced)	1200	**6-15**	--	--	**0.29**	**0.36**	**0.42**	**0.56**	--	--

Table 5-7. Characteristics of Thermal Insulations. (Continued)

Form	Material (Composition)	Accepted Max.Temp. For Use °F(1)	Density lb./cu. ft.	K = Typical Conductivity at Mean Temp. °F (Btu/H/ft^2/° per inch)							
				40	70	100	200	300	500	700	900
Pipe Insulation (con'd)	Plastics (foamed)	175	1-6	0.26	0.28	0.31	--	--	--	--	--
	Rubber (foamed)	150	5	0.23	0.24	0.25	--	--	--	--	--
	Vegetable and animal fiber:										
	Wool felt	180	20	0.29	0.31	0.33	--	--	--	--	--
	Hair felt or hair felt plus jute	180	10	0.27	0.28	0.30	--	--	--	--	--
Insulating cement	85% magnesia	600	18	--	--	0.46	0.52	0.58	--	--	--
	Mineral wool (rock, slag or glass):										
	With colloidal clay binder	1800	24-30	--	--	0.49	--	0.61	0.73	0.83	--

NOTES: (1) These temperatures are generally as maximum. When operating temperature approaches these limits the manufacturer's recommendations should be followed.

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installation. For large areas or long piping runs, substantial savings may be realized by factory forming, cutting or covering. Valves and pipe fittings, especially large ones, may be economically insulated with factory made prefabricated shapes. Equipment requiring periodic servicing will be equipped with removable, reusable insulation.

e. *Miscellaneous materials.* Complete insulation systems include accessory materials such as fasteners, adhesives, reinforcing wire meshes and screens, bandings and binder wires, coverings or laggings, and finishes. All insulations will be sealed or closed at joints and should be arranged to accommodate differential expansions between piping or metal structures and insulations.

f. Cold surface materials. Cold surface insulation materials will be selected primarily for high resistance to moisture penetration and damage, and for avoidance of corrosion where wet insulation materials may contact metal surfaces. Foamed plastics or rubber and cellular (or foamed) glass materials will be used wherever practicable.

5-15. Control of useful heat losses

a. *General.* Control of losses of useful heat is the most important function of insulations. Substantial investments for thermal insulation warrants careful selection and design.

b. Durability and deterioration. Most conventional insulating materials are relatively soft and fragile and are subject to progressive deterioration and loss of effectiveness with the passage of time. Insulation assemblies which must be removed for maintenance or which are subject to frequent contact with tools, operating equipment and personnel, or are subject to shock or vibration, will be designed for maximum resistance to these forces.

5-16. Safety insulation

a. General Insulation for personnel protection or safety purposes will be used to cover dangerously hot surfaces to avoid accidental contact, where heat loss is not itself an important criteria.

b. General safety criteria. Safety or burn protection insulations will be selected to insure that outside insulation surfaces do not exceed a reasonably safe maximum, such as *140* “F.

c. Other criteria Close fitting or sealing of safety insulation is not required. Metal jacketing will be avoided due to its high conductivity in contact with the human body.

5-17. Cold surface insulation

a. Applications. Insulations for cold surfaces will be applied to refrigeration equipment, piping and ductwork, cold water piping, and to air ducts bringing outside air into power plants and HVAC systems.

b. Criteria. In most cases, cold surface insulations will be selected to prevent icing or condensation. Extra insulation thickness is not normally economical for heat absorption control.

5-18. Economic thickness

a. General. Economic thickness of an insulation material (ETI) is a calculated parameter in which the owning costs of greater or lesser thicknesses are compared with the relative values of heat energy which might be saved by such various thicknesses. The method is applicable only to systems which are installed to save useful heat (or refrigeration) and does not apply to safety insulation or anti-sweat (condensation) materials.

b. Economic criteria. The general principle of ETI calculations is that the most economical thickness of a group or set of thicknesses is that one for which the annual sum of owning costs and heat loss costs is a minimum. Generally, thicker insulations will represent higher owning costs and lower heat loss costs. The range of thicknesses selected for calculation will indicate at least one uneconomical thickness on each side of the indicated ETI. Refer to Fig ure *5-1* for a generalized plot of an ETI solution.

c. Required data. The calculations of ETI for a particular insulation application involves routine calculations of costs for a group of different thicknesses. While calculations are readily performed by computers, the required input data are relatively complex and will include energy or fuel prices with allowance for future changes, relative values of particular heat sources or losses, depreciation and money cost rates, costs of complete installed insulation systems, conductivities, temperatures, air velocities and operating hours. Standard programs are available for routine calculations but must be used with care. The most uncertain data will be the installed costs of alternative insulation systems and thicknesses. Assumptions and estimates of such costs will be as accurate as possible. Refer to the publications and program systems of the Thermal Insulation Manufacturers Association (TIMA) and of leading insulation manufacturers.

5-19. Freeze protection

a. Application. Freeze protection systems are combinations of insulation and heat source materials arranged to supply heat to exposed piping or equipment to prevent freezing in cold weather.

b. Insulaztion materials. Conventional insulation materials will be used and selected for general heat loss control purposes in addition to freeze protection. Insulation will be such as not to be damaged by

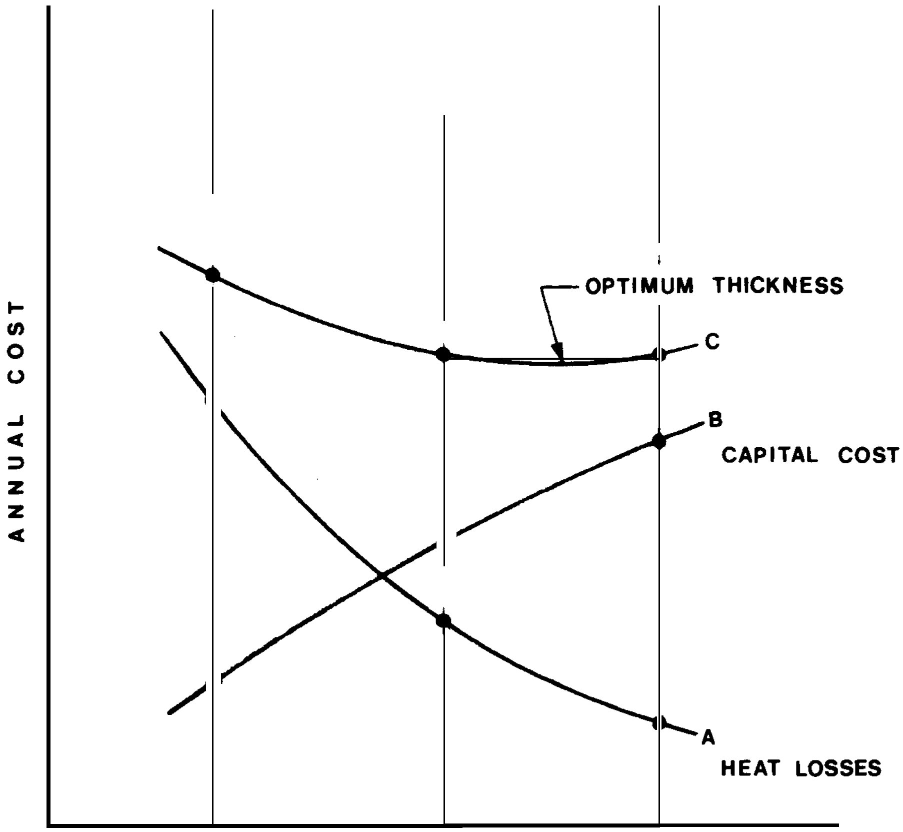

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Figure 5-1. Economical thickness for heat insulation (typical curves).

the heat source or by extended exposure to weather and moisture.

c. Design criteria. In general, the insulation for a freeze protection system will be selected for maximum overall coldest ambient temperatures. Allowance for wind conditions will be made.

d. Heat sources. Electrical heating tape will generally be used to supply the correct heat flow to the protected surface. Steam and ho water tracing may also be used with provisions to avoid loss of steam or water. In either case, the required heat supply will be sufficient to meet the heat loss of the insulation under the combination of design ambient and pipe line surface temperature.

Section V. CORROSION PROTECTION

5-20. General remarks

The need for corrosion protection will be investigated. Cycle fluids will be analyzed to determine treatment or if addition of corrosion inhibitors is required. Corrosion protection of items external to the cycle is generally accomplished by more conventional methods such as:

U. Selection of corrosion resistant materials.

b. Protective coatings.

c. Cathodic protection.

Section VI. FIRE PROTECTION

5-21. Introduction

Fire protection will be provided in order to safeguard the equipment and personnel. Various systems will be installed as required to suit the particular type of fire which can occur in the station. This manual discusses various fire protection systems and their general application in power plants. Reference will be made to TM 5-812-1 for specific requirements for military installations. Further details may be found in the National Fire Protection Association (NFPA) Codes and Standards.

5-22. Design considerations

a. Areas and equipment to be protected. The following are some of the major areas which will be investigated to determine the need for installing fire protection facilities.

(1) Main and auxiliary transformers.

(2) Turbine lubricating oil system including the oil reservoir, oil, cooler, storage tanks, pumps and the turbine and generator bearings.

(3) Generator hydrogen cooling system including control panels, seal oil unit, hydrogen bottles and the purification unit.

(4) Coal storage bunkers, fuel oil storage tanks and the burner front of the steam generator.

(5) Emergency diesel generator and its oil storage tank.

(6) Office and records rooms.

(7) Control room.

(8) Relay, computer, switchgear and battery rooms.

(9) Shops, warehouses, garages and laboratories.

(10) Personnel locker rooms, lunch rooms and toilets.

b. Types of systems. The following is a brief description of the various types of systems and their general application.

(1) *Water spray and deluge system.* This type of system consists of open type sprinkler heads attached to a network of dry (not water filled) piping which is automatically controlled by a fully supervised fire detection system which also serves as a fire alarm system. When a fire is detected, an automatic deluge valve is tripped open, admitting water to the system to discharge through all of the sprinkler heads. The system may be subdivided into separately controlled headers, depending on the area to be covered and the number of sprinkler heads required. The usual pressure required at the sprinkler heads is about 175 psi and the piping should be properly sized accordingly. A water spray deluge sprinkler system will be provided where required in open areas and areas requiring the protection of the piping from freezing, such as the steam generator burner fronts; the generator hydrogen system; the main and auxiliary transformers; and unheated shops, garages, warehouses and laboratories.

(2) *Water spray pre-action and deluge system.* This type of system is similar to the above water spray deluge system, except that it contains closed type sprinkler heads which only discharges water through those sprinklers whose fixed temperature elements have been opened by the heat from a fire. This system will be utilized for the turbine and generator bearings and for the above water spray deluge sprinkler system areas where more localized control is desired.

(3) *Wet pipe sprinkler systems.* This wet pipe system utilizes a water filled piping system connected to a water supply and is equipped with sprinklers having fixed temperature elements which each open individually when exposed to a high temperature due to a fire. The areas where wet pipe sprinkler systems will be used are heated shops, garages, warehouses, laboratories, offices, record rooms, locker rooms, lunch rooms and toilets.

(4) *Foam extinguishing systems.* Foam fire extinguishing systems utilize a foam producing solution which is distributed by pipes equipped with spray nozzles or a fuel tank foam entry chamber for discharging the foam and spreading it over the area to be protected. It is principally used to form a coherent floating blanket over flammable and combustible liquids which extinguish (or prevent) a fire by excluding air and cooling the fuel. The foam is usually generated by mixing proportionate amounts of 3% double strength, low expansion standard foam concentrate using either a suitably arranged induction device with (or without) a foam storage-proportioning tank to mix the foam concentrate with a water stream from a fire water header. A specially designed hand play pipe, tank foam chamber or open sprinklers aspirate the air to form the foam to blanket the area to be protected. The deluge water entry valve to the system may be manually or automatically opened. Foam systems will be installed in power plants to protect fuel oil areas, lubricating oil systems, and hydrogen seal oil systems.

(5) *Carbon dioxide extinguishing systems.* This type of system usually consists of a truck filled low pressure refrigerated liquid carbon dioxide storage tank with temperature sensing controls to permit the automatic injection of permanently pipe carbon dioxide into areas to be protected. The system usually includes warning alarms to alert personnel whenever carbon dioxide is being injected into an actuated area. Carbon dioxide extinguishing systems of this total flooding type will be utilized to extinguish coal bunker fires and for electrical hazard areas such as in battery rooms, electrical relay rooms, switchgear rooms, computer rooms and within electrical cabinets.

(6) *Halogenated fire extinguishing systems.* This type of system utilizes specially designed removable and rechargeable storage containers containing liquid HaIon at ambient temperature which is superpressurized with dry nitrogen up to 600 psig

pressure. These manifolded containers are located as closely as possible to the hazards they protect and include connecting piping and discharge nozzles. There are two types of systems. The total flooding system is arranged to discharge into, and fill to the proper concentration, an enclosed space or an enclosure about the hazard. The local application system is arranged to discharge directly onto the burning material. Either system may be arranged to protect one or more hazards or groups of hazards by so arranging the piping and valves and may be manually or automatically actuated. Halon is a colorless and odorless gas with a density of approximately five times that of air, and these systems must include warning alarms to alert personnel whenever the gas is being ejected. However, personnel maybe exposed to Halon vapors in low concentrations for brief periods without serious risk. The principal application of Halon extinguishing systems is where an electrically nonconductive medium is essential or desired or where the cleanup of other media presents a problem, such as in control rooms, computer rooms, chemical laboratories and within electrical panels.

c. Automatic fire detectors. All fire protection systems will normally be automatically alarmed and actuated; however, some special conditions may require manual actuation on an alarm indication. A manual actuation will be included to provide for emergencies arising from the malfunction of an automatic system. The primary element of any fire protection system is the fire detection sensing device which is actuated by heat detectors which detect abnormally high temperature or rate-of-temperature rise, or smoke detectors which are sensitive to the visible or invisible particles of combustion. The ionization type of smoke detector belongs in this category.

5-23. Support facilities

To support the fire protection water systems, an assured supply of water at an appropriate pressure is necessary. This water supply will be provided from an underground fire water hydrant system main if one is available in the area and/or by means of an elevated head storage tank or by fire pumps which take their suction from a low level storage tank. For cases where the water supply pressure is inadequate to fill the tank, fill pumps will be provided. Fire pumps will be electric motor driven, except that at least one should be of the engine driven or of the dual drive type.